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Comparison of potato yield, quality, weed control and economics obtained with different mulch materials

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Abstract
To find out a suitable mulch material for potato production is an important issue for the farmers. The aim of the present study was to evaluate the effect of mulching on yield, quality, weed growth and economics of potato. A field experiment was conducted at Vegetable Research Centre (VRC), G.B. Pant University of Agriculture and Technology Pantnagar during *rabi* season to evaluate the performance of mulching on potato production. For meet up the demand six treatments viz. Black polyethylene mulch (25μ), Sugarcane dry leaves of 2.5 cm thickness, sugarcane dry leaves of 5.0 cm thickness, paddy straw mulch of 2.5 cm thickness, paddy straw mulch of 5.0 cm thickness and control (without mulch) were used to find the best materials that can help the farmers to improve their production practice. Now a days mulching has become an important factor for potato production. The results concluded that sugarcane dry leaves mulch of 5.0 cm thickness was found most effective and more beneficial than rest of the treatment for all the characters of potato while the minimum values of the same was found under control (without mulch) treatment. All the mulches have significant influence on the yield, quality characters, weed population and economics of the experiment. Weeds are one of the most limiting factors in potato cultivation. This study aims to evaluate the effects of mulching on the prevalence of weeds and to discuss the implications on potato production. The economic consideration among all the treatments revealed that the sugarcane dry leaves of 5.0 cm thickness gave the highest net income. The positive response of various organic mulches on, yield, quality, weed growth and economics may be due to the fact that mulch treatments provide a congenial environment for proper plant growth which ultimately improves these parameters.

Keywords: Potato, organic mulching, sugarcane, paddy, weed, economics yield

Introduction
Potato is a staple food which accounts for 37% of the total potato production in world. Potato (*Solanum tuberosum* L.) rate fourth among the world's various agricultural products in production volume, after wheat, rice and corn (Fabeiro *et al*., 2001) [13]. Production of potato (*Solanum tuberosum* L.) takes a very important place in world agriculture, with a production potential of about 327 million tons harvested and 18.6 million hectares planted area (FAO, 2006) [12]. It is a temperate crop (Onder *et al*., 2005) [33] that grows and yields well in cool and humid climates or seasons, yet it is grown in climatic regions from the tropics to the sub-polar and comprises a major food crop in many countries. The ideal conditions for potato growth include high and nearly constant soil matric potential, high soil oxygen diffusion rate, adequate incoming radiation and optimal soil nutrients (Yuan *et al*., 2003) [47]. In natural environment plants are subjected to many stresses that can have negative effect on growth and yield. India is a developing country and is primarily an agriculture-based economy. Potato is one of the most important crops in India.

Mulching is an agrotechnical technique that directly determines the microclimate of plants in several ways. It reduces evaporation (Gao and Li, 2005; Zhao *et al*., 2012) [17, 48], warms the surface soil layer after sowing (Wang *et al*., 2003; Zhao *et al*., 2012) [42, 49], increases the microbiological activity (Yang *et al*., 2003; Aguero *et al*., 2008) [46, 1] and inhibits the development of most one-year and perennial weeds (Jodaugiene *et al*., 2006a, b) [23]. It is a preventive layer covering the surface of the soil and it contains organic and inorganic materials (Singh *et al*., 2015) [39]. Soil covering with mulch also reduces the destructive action of rain drops, prevents formation of crust and maintains favorable air regime of the land. Through greater heat accumulation, as well as the photo-physiological effect of reflected diffused light, soil mulching significantly affects potato yield quantity and quality, the bulk density and marketability of the tubers, as well as the greater content of protective, colorful compounds (Momirovic *et al*., 2011) [32]. Potato is sensitive crop to the soil moisture. Because of wider spacing and slow growth of potato during early stage of crop encourage the heavy infestation of weeds. The application of thick organic mulch as soil cover can reduce the weed infestation and evaporation losses improve plant growth resulting in increased crop yield.

For soil mulching, different inorganic and organic mulch are used. White/black foil is characterized by extremely high reflection which allows cultivation of crops in the warmer part of the vegetation season. Black mulch foils are used for vegetable cultivation in general; the advantages are mainly related to water savings (up to 50% in drip-irrigation system), successful weed control, better phytosanitary conditions and directed carbon dioxide emissions from soil to photosynthetic area (Chimney effect). Dark foil can be considered as absolutely non-toxic herbicide, harmless to plants, land and man (Kovacevic and Momirovic, 2008). Straw and sugarcane leaves are the most commonly used material for ground covering in the crop and vegetable production because of its good thermal insulation properties. The temperature of the soil under the straw can be 5-8° C lower than the temperature of bare soil which is especially important in the summer. Organic matter is essential to maximize potato production and sustain agricultural production while minimizing negative impacts on the soil fertility (Ferdous *et al*., 2017a) [13]. Soil mulching which covers the soil at the base of cultivated plants with a layer of protective material (Bégin *et al*., 2001) [4] has been widely used in the world for growing crops like potatoes. The benefits of mulching potatoes include saving irrigation water (Singh *et al*., 2015; Wang and He, 2012) [39, 45], reducing soil erosion (Edwards *et al*., 2000) [11] and leaching of fertilizer (Begin *et al*., 2001) [4], controlling weeds or reducing the dose of herbicide (Ferdous *et al*. 2017b; Kasirajan and Ngouajio, 2012) [16, 26], enhancing early growth, harvest (Zhao *et al*., 2014) and increasing yields (Ferdous *et al*., 2017b; Singh *et al*., 2015) [16, 39]. Soil temperature and moisture has depended on the physical properties of mulch, e.g. thermal conductivity, and their interaction with environmental condition. Mulching also helps in faster plant emergence; early canopy development of potato plants and higher marketable and total tuber yield (Mohammad *et al*., 2002) [30]. The aim of the present investigation was to evaluate Performance of different mulch materials (organic and plastic mulch) on yield, quality, weed population and economics of potato grown in the tarai region of uttarakhand.

Material and Methods

The experiment was conducted at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, district Udham Singh Nagar, Uttarakhand. The trial was carried out during *rabi* season under locally available mulch materials using organic and inorganic materials along with control i.e. without mulch or traditional practice (Table 1).

Table 1: Treatment details

S. No.	Treatments	Symbols
1	Black polyethylene mulch (25µ)	T_1
2	Sugarcane dry leaves mulch (2.5cm)	T_2
3	Sugarcane dry leaves mulch (5.0 cm)	T_3
4	Paddy straw mulch (2.5 cm)	T_4
5	Paddy straw mulch (5.0 cm)	T_5
6	Control (without mulch)	T_6

For planting the crop disease free, medium sized (25 to 50g) and well sprouted tubers were selected as seed tuber. The seed treatment was done with Boric acid (3%) for 15 minutes prior to planting. The treated tubers were planted in furrows and covered by soil by making ridges. The distances between row to row and plant to plant were maintained as 60 cm and 20 cm, respectively. Mulch materials were applied in each plot after one month of planting. The 2.5 cm and 5.0 cm thick layer of paddy straw and sugarcane dry leaves mulch material were used as mulch. The control plots were left without any mulch i.e. traditional practice.

The observations were recorded under different parameters like Number of haulm per hill, number of leaves per hill, diameter of haulm per hill, Tuber yield, Average tuber weight, grade wise number of tuber per hill, grade wise yield of tuber per hill (kg), Weed population/ m^2, Dry weight of weeds/ m^2, Percent dry matter content of tubers, Total Soluble Solids (%) and Economics of the different treatments.

Table 2: Trail details

Sr. No	Items	Details
1	Total number of treatments	06
2	Number of replications	03
3	Number of plots	18
4	Number of rows per replication	5
5	Number of tubers planted per row	15
6	Number of tubers planted per plot	75
7	Gross plot size	4.2m× 3.6m
8	Net plot size	3.6m×3.6m
9	Spacing	60× 20 m^2
10	Main irrigated channel	1m
11	Sub-irrigated channel	0.75 m
12	Variety	K. Jawahar

The data recorded during the course of experiment were statistically analyzed using randomized block design. Valid conclusions were drawn by performing analysis of variance. To evaluate the significance of the difference between means of two treatments, critical difference (at 5% level of significance) was calculated using following formula:

$$CD = \sqrt{2} \times EMS \div r \times t$$

Where,

CD = critical difference

t = table value of ‘t’ at error degree of freedom

r = number of replications

EMS = error mean square

Result and Discussion

Comparison of potato yield and yield attributes obtained with different mulch materials

Treatments differed significantly with respect to number of tubers per hill. It is obvious from the Table-6 that there was a slight increase in number of tubers per hill under mulched plot (table 3). Maximum number of tubers per hill (8.68) was recorded under sugarcane dry leaves mulch of 5.0 cm thickness which was at par with paddy straw mulch of 2.5 cm thickness and black polyethylene (25µ) mulch. The minimum number of tubers was recorded under control (without mulch) plot. The effect of organic and inorganic mulch with respect to the yield of tubers per hill was found significant. The maximum tuber yield per hill was recorded in sugarcane dry leaves mulch of 5 cm thickness.

It was noticed that all the organic mulch treatments increased tuber yield per hill as compared to inorganic mulch (black polyethylene) and control (without mulch). It was observed that the maximum tuber weight was recorded in sugarcane dry leaves mulch of 5.0 cm thickness which was at par with sugarcane dry leaves mulch of 2.5 cm thickness, paddy straw mulch of 2.5 and 5 cm thickness. The minimum tuber weight was recorded black polyethylene mulch. Such a result has been supported by the findings of Sadawarti *et al*., (2013) [37]. Kumar *et al*., (2003) [27] has also suggested that potato leaves close their stomata at relatively low soil moisture regime leading to faster decrease in photosynthesis and transpiration rate than other field crops leading to lower yields which has also been reflected in the present study. Mulching also resulted in higher tuber yield in all the yield categories over no mulching. Such beneficial effects of mulching have been demonstrated in the results achieved by Kar and Kumar (2007) [24].

The total tuber yield varied from 206.5 to 279.1 q/ha. and was higher in sugarcane dry leaves mulch of 5.0 cm thickness (279.11q/ha) followed by sugarcane dry leaves mulch of 2.5 cm thickness (251.17q/ha) whereas, control (without mulch) treatment yielded minimum tuber yield (206.53q/ha) which was 35% low than the yield obtained in sugarcane dry mulch of 5 cm thickness. Similar results were found by different investigators. Singh *et al.*, 1975, reported that pine needle mulch gave better yield in three successive years. Battacharjee *et al.,* 1979, reported that use of paddy straw mulch increased tuber yield by 35 q/ha in comparison to control. Singh *et al.,* 1987, reported that mulching of potato with paddy straw gave better tuber yield as compared with without mulch. Sahoo *et al.,* 2006, reported that potato crop mulching increased tuber yield over without mulched plot. Progressive increase in these parameters owing to mulching may attributed that mulching provide congenial environment for tuber development by maintaining soil temperature and conserving soil moisture. Owing to many advantages, mulching improves crops yields both in quantity or quality (Wang *et al*., 2008) [43], and increases water use efficiency (Wang *et al*., 2008; Ferdous *et al*., 2017b) [43, 16].

Table 3: Comparison of Number of tuber/hill, Tuber yield /hill (kg), Average tuber weight (g) and Total tuber yield (q/ha) of Potato Obtained with different mulch materials

Mulch treatment	Number of tuber/hill	Tuber yield /hill (kg)	Average tuber weight (g)	Total tuber yield (q/ha)
Black polyethylene (25µ)	8.27	0.272	33.69	249.24
Sugarcane dry leaves (2.5cm thickness)	7.48	0.339	43.75	251.17
Sugarcane dry leaves (5cm thickness)	8.68	0.348	45.72	279.11
Paddy straw (2.5cm thickness)	8.45	0.324	43.71	232.49
Paddy straw (5cm thickness)	7.38	0.317	43.36	230.03
Control (without mulch)	7.30	0.280	35.33	206.53
S.Em.±	0.19	0.105	1.04	0.42
C.D. at 5%	0.61	0.331	3.28	1.32

The differences due to different treatments on grade wise number of tubers were significant during the investigation (table 4). Maximum numbers of ‘A’ grade tubers were recorded in sugarcane dry leaves mulch of 5.0 cm thickness which was followed by paddy straw mulch of 2.5 cm thickness. The minimum values were found with black polyethylene mulch and control treatment (without mulch). Maximum number of ‘B’ grade tubers were found in black polyethylene mulch which was followed by sugarcane dry leaves of 5 cm thickness. Minimum number of ‘B’ grade tubers were found with control treatment (without mulch). ‘C’ grade tubers were noticed maximum in control (without mulch) treatment and minimum in paddy straw mulch of 5 cm thickness. Maximum number of ‘D’ grade tubers were found in sugarcane dry leaves of 2.5 cm thickness which was followed by control (without mulch) treatment and minimum was recorded in paddy straw mulch of 2.5 cm thickness.

Table 4: Comparison of grade wise number of tuber per hill of Potato Obtained With Different Mulch Materials

Mulch treatment	Grade A	Grade B	Grade C	Grade D
Black polyethylene (25µ)	34.00	145.00	168.00	180.00
Sugarcane dry leaves (2.5cm thickness)	45.33	107.33	170.0	189.00
Sugarcane dry leaves (5cm thickness)	47.00	127.00	171.00	178.00
Paddy straw (2.5cm thickness)	46.00	119.67	155.00	145.00
Paddy straw (5cm thickness)	39.00	132.00	152.00	152.33
Control (without mulch)	30.33	105.33	182.00	187.33
S.Em.±	0.17	0.25	0.24	0.17
C.D. at 5%	0.54	0.79	0.79	0.54

The yield of ‘A’ grade tubers were recorded maximum in sugarcane dry leaves mulch of 5.0 cm thickness which was at par with sugarcane dry leaves mulch of 2.5 cm thickness. Minimum was recorded with black polyethylene and control treatment. The maximum yield of ‘B’ and ‘D’ grade tubers was recorded in sugarcane dry leaves of 2.5 cm thickness which was followed by other organic mulches whereas minimum was recorded under black polyethylene and control treatment. ‘C’ grade recorded maximum yield in paddy straw mulch of 5 cm thickness which was followed by control treatment, minimum value of same tubers were found in sugarcane dry leaves of 5 cm thickness (table 5).

Table 5: Comparison of grade wise yield of tuber per hill of Potato (kg) obtained with Different Mulch Materials

Mulch treatment	Grade A	Grade B	Grade C	Grade D
Black polyethylene (25µ)	5.73	10.66	7.67	2.64
Sugarcane dry leaves (2.5cm thickness)	7.28	12.67	8.00	3.09
Sugarcane dry leaves (5cm thickness)	7.42	11.92	8.07	2.80
Paddy straw (2.5cm thickness)	7.26	11.73	7.13	2.66
Paddy straw (5cm thickness)	4.97	12.33	9.33	2.67
Control (without mulch)	5.73	9.75	9.27	2.91
S.Em.±	0.12	0.28	0.23	0.55
C.D. at 5%	0.38	0.43	0.73	0.17

These could be attributed to the higher temperature and humidity under mulched during the early development. As a result, mulching led to the higher emergence rate and strong seedling, accordingly increased the stems and branches per plant, leading to more number of tubers in tuber initiation. Furthermore the extended period of tuber initiation could have also promoted the tuber bulking. Consequently, the number and yield of good grade tubers in mulching were highest, especially mulched condition. The mulching practice affects crop growth and development in various ways. It decreases the amount of water loss due to evaporation (Wang *et al*., 2008; Li *et al*., 2013) [43, 28] enhances soil water infiltration (Gan *et al*., 2013), distributes soil moisture again and therefore relieves water stress to some degree (Chakraborty *et al*., 2008) [6]. Owing to many advantages, mulching improves crops yields both in quantity or quality (Wang *et al*., 2008) [43], and increases water use efficiency (Wang *et al*., 2008; Ferdous *et al*., 2017b) [43, 16].

Comparison of potato dry matter (%) and T.S.S. (%) obtained with different mulch materials

The mulching significantly improved the quality of the potato tuber. The overall effect of different sources on dry matter was found significant during the investigation. The maximum dry matter content of tuber was recorded under control treatment (without mulch) followed by black plastic mulch with sugarcane dry leaves mulch of 2.5 cm thickness, it was recorded minimum in paddy straw mulch of 5.0 cm thickness. The overall effect of different sources on T.S.S content found significant during the investigation.

Table 6: Comparison of Potato T.S.S (%) and Dry matter content (%) Obtained with different Mulch Materials

Mulch treatment	T.S.S. (%)	Dry matter (%)
Black polyethylene (25µ)	3.83	15.52
Sugarcane dry leaves (2.5cm thickness)	3.93	15.45
Sugarcane dry leaves (5cm thickness)	3.33	13.53
Paddy straw (2.5cm thickness)	3.76	13.66
Paddy straw (5cm thickness)	4.23	11.72
Control (without mulch)	3.76	16.54
S.Em.±	0.52	0.29
C.D. at 5%	1.65	0.92

The overall effect of different sources of mulches on T.S.S content was found significant during the investigation. The T.S.S content in tuber ranged from 3.33 to 4.23 percent. The maximum T.S.S content was observed in paddy straw mulch of 5.0 cm thickness which was at par with all the treatments. The minimum T.S.S content was recorded with sugarcane dry leaves mulch of 5.0 cm thickness.

The increase in the quality parameters due to mulching may be attributed to the fact that sugarcane dry leaves and paddy straw mulch might have added organic matter to the soil after decomposition, which might have resulted in better plant growth, that governs by soil temperature with minimum fluctuation and favorable soil moisture. The findings are in close conformity with the findings of Wadas *et al.* (2001) and Trifonova (1980) [41, 40].

Comparison of weed population/m^2, dry weight of weeds (g/m^2) and economics obtained with different mulch materials

All the treatment comprised of inorganic and organic mulch material showed significant effect on the weed population during the investigation. The weed population varied from 4.10 to 9.33 m^2. Maximum numbers of weeds were recorded in control treatment (without mulch) whereas, the minimum population was recorded with sugarcane dry leaves mulch of 5.0 cm thickness, which was 56 % lower than the control treatment.

The density of different weed species was influenced significantly by mulching treatments. Mulching significantly reduced the density and dry matter of all the weeds over the non-mulching treatment.

The data regarding dry weight of weed per m^2 area are present in Table-7. The overall effect of different inorganic and organic mulch found significant during the investigation. Dry weight of weeds varied from 1.61 to 3.36g. Highest dry weight of weeds recorded under control treatment i.e. without mulch whereas, the lowest dry weight of weed recorded under sugarcane dry leaves mulch of 2.5 cm thickness.

Table 7: Comparison of Weed population/m^2 and Dry Weight of Weeds (g/m^2) obtained with Different Mulch Materials

Mulch treatment	Weed population/m^2	Dry Weight of Weeds (g/m^2)
Black polyethylene (25µ)	6.67	2.49
Sugarcane dry leaves (2.5cm thickness)	5.363	1.61
Sugarcane dry leaves (5cm thickness)	4.10	1.67
Paddy straw (2.5cm thickness)	5.30	2.20
Paddy straw (5cm thickness)	4.50	1.67
Control(without mulch)	9.33	3.36
S.Em.±	0.55	3.36
C.D. at 5%	0.79	0.58

The critical observation of data revealed that organic mulches particularly sugarcane dry mulch was found very effective in reducing the weed's dry weight rather than inorganic mulch and control treatment. This might be due the physical hindrance of mulching which reduced the germination and growth of weeds by reducing the light for breaking the dormancy of weed seed.

Mulch material that remains on the soil surface can be used to add soil organic matter (Dabney *et al*., 2001) [7], prevent soil erosion, increase soil water retention, improve soil health (Wang *et al*., 2011) [44], and suppress arthropod and weed pests as well as diseases (Ferdous *et al*., 2017b; Gonzalez-Martin *et al*., 2014) [16, 20]. This organic matter increase crop yield (Ferdous *et al*. 2011a,b; Ferdous *et al*. 2014; Sarker *et al*. 2010; Rahman *et al*. 2011) [16, 15, 39, 36]. Organic mulch associated with no-till farming is well-known for its soil health benefits (Doran, 2002) [9].

Comparison of cost - Benefit ratio obtained with different mulch materials

Cost: benefit ratio is an indication of the production efficiency of the treatments. It dictated the value of rupees obtained in production system per rupee invested. Highest cost: benefit ratio of 1:2.05 was obtained with sugarcane dry leaves mulch of 2.5 cm thickness. It was followed by sugarcane dry leaves mulch of 5 cm thickness having value of 1:1.97 whereas, lowest cost : benefit ratio of 1:1.55 was obtained under black polythene mulch treatment.

Table 8: Comparison of cost - Benefit ratio obtained with different mulch materials

Mulch treatment	Gross expenditure	Gross income	Net income	C:B ratio
Black polyethylene (25µ)	90104	139775	49671	1.55
Sugarcane dry leaves (2.5cm thickness)	77411	159260	81849	2.05
Sugarcane dry leaves (5cm thickness)	80925	159905	78980	1.97
Paddy straw (2.5cm thickness)	80367	153055	72688	1.90
Paddy straw (5cm thickness)	86879	165645	78766	1.90
Control (without mulch)	73984	139350	65366	1.88

The cost of the cultivation varied in the range of Rs. 90104 to 73984/ha with minimum in control treatment (without mulch) and maximum in black polyethylene mulch treatment. The increase in cost of cultivation was mainly due to more involvement of variable inputs like (mulch) in black polyethylene mulch. The maximum gross income was found in paddy straw mulch of 5 cm thickness (Rs 165645/ha) followed by sugarcane dry leaves mulch of 5 cm thickness (Rs 159905/ha) during the investigation. It might be due to increase in the yield under these treatments. Highest net return was incurred with sugarcane dry leaves mulch of 2.5 cm thickness (Rs.81849/ha) treatment followed by sugarcane dry leaves mulch of 5 cm thickness (Rs.78980/ha) and paddy straw mulch of 5 cm thickness (Rs. 78766/ha). It might be also due to increase yield in these treatments. Benefit: cost ratio was incurred maximum in sugarcane dry leaves mulch of 2.5 cm thickness (2.05) followed by sugarcane dry leaves mulch of 5 cm thickness (1.97), paddy straw mulch of 2.5 cm thickness and paddy straw mulch of 5 cm thickness (1.90). Minimum net return (Rs 49671/ha) and benefit cost ratio (1.55) incurred under black polyethylene mulch treatment. The variations in return might be because of variations in the variable inputs involved and yield of crop under different treatments. The reults are in close conformity with the findings of Rahaman *et al.* (2004) kumar *et al.* (2007) [34, 24].

Conclusion

By considering different yield contributing characters, quality, weed population and economics the organic mulch material, sugarcane dry leaves of 5 cm thickness may be the most useful for potato cultivation. Mulches contribute to weed management in crops by reducing weed seed germination, blocking weed growth, and favouring the crop by conserving soil moisture and sometimes by moderating soil temperature. Mulching in the form of cover crops and practicing reduce tillage have some ecological advantages over conventional land preparation tasks such as plowing and disking the entire field as they are generally less disrupted to the soil environment. It can be summarized that mulching proved useful in increasing yield attributes, quality, weed control and economics of potato crop significantly compared to control.

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